The occurrence of Middle-Miocene volcanism at Mount Hermon, northern Israel

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ABSTRACT


A 30-m-thick basaltic dike that intrudes the Lower Cretaceous Mas’ada Formation at the southeastern flank of Mount Hermon was studied. The age of the dike, obtained by K–Ar method, is 13.4 ± 0.2 Ma. This age provides the first evidence that Middle-Miocene volcanic activity took place in the northern Golan Heights. The age and the basanite composition of the dike are similar to the known age and composition of volcanics from the Yizre’el Valley and Kokhav HaYarden. These findings should be taken into consideration when evaluating the amount of left-lateral offset achieved by the end of the Middle Miocene along the Dead Sea Transform.

INTRODUCTION

During mid-Cenozoic times magmatic activity commenced throughout a vast region, extending from East Africa through Saudi Arabia and Israel up to southern Turkey (Gass, 1970; Camp and Roobol, 1992). Coevally with the magmatic activity, this region went through rifting and faulting that led to the separation of the Arabian plate from the African plate along the Red Sea rift and the Dead Sea Transform (DST). This volcano-tectonic system is well preserved in Harrat Ash Shaam, the largest volcanic field in the Arabian plate, extending over 50,000 km² and covering part of Saudi Arabia, Jordan, Syria, and Israel. About 130 K–Ar age determinations show that the ages of the Harrat Ash Shaam system in northeastern Jordan range from Late Oligocene (~26 Ma) to Quaternary (Ilani et al., 2001). Early Miocene volcanics also occur in the Damascus Basin (~20 Ma, Roperch and Bonhomme, 1986; Giannérini et al., 1988)). There was very limited volcanic activity between ~20 to 12 Ma in most of the western Arabian plate (Camp and Roobol, 1992). A renewal of volcanism along this region began at ~12 Ma with activity along WNW to NW-trending fissure eruptions and basaltic flows recorded in northeastern Jordan (Tarawneh et al., 2000). Nevertheless, volcanic activity in northeastern Israel both west of the DST in the Lower Galilee and east of the DST in the southern Golan Heights commenced at ~17 Ma and continued during this quiescent period (Shaliv, 1991). West of the DST, Early- and Middle-Miocene volcanic flows and small intrusions occur in the SE Galilee and nearby areas (Fig. 1), including the Yizre’el Valley, Kokhav HaYarden, Giv’at HaMoreh, Mt. Gilbo’a, Poriyya, and Nahal Tavor (Oppenheim, 1962; Schulman, 1962; Shaliv, 1991; Aharon, 1997). These volcanics, termed “Lower Basalt” locally, form a section more than 600 m thick that overlies pre-Neogene volc...
Fig. 1. Map showing the Middle-Miocene volcanics in northeastern Israel and the location of the study area.
strata. East of the DST, in the southern Golan Heights, a few basaltic flows of 15–12 Ma are found, including outcrops in Mevo Hamma (Shaliv, 1991).

Prior to this study, Lower Basalt volcanics were not found in the area between the southern Golan Heights and Mt. Hermon. It was unclear if younger (Plio-Pleistocene) volcanics obscure the Miocene volcanism or the lack of Miocene outcrops represents a spatial gap in the volcanic activity in that area. It was suggested that this area was previously adjacent to the SE Galilee during the Early and Middle Miocene before significant left-lateral offset along the DST took place (Garfunkel, 1989).

In the course of mapping the Metulla quadrangle, we came across a new road cut (Israel Grid Coordinate 22026E/29342N) near the village of Mas’ada in the southeastern flank of Mt. Hermon. Along this road cut, a 30-m-thick WNW-trending basaltic dike intrudes the SE-dipping limestone beds of the Lower Cretaceous Mas’ada Formation (Fig. 2, inset). The vertical termination of the dike is arrested within the limestone beds. The dike is henceforth called the Mas’ada dike. Unfortunately, the road cut was later covered by a stone wall as part of an agriculture terrace (Fig. 2, inset), preventing further structural and paleomagnetic study of the dike. Nevertheless, an irregular relict of the basaltic intrusion can be seen along the northern side of Nahal Sa’ar, within a tilted block of the Mas’ada Formation (Israel Grid Coordinate 22046E/29331N). This paper reports on the age and geochemistry of the Mas’ada dike and discusses their implications for understanding the volcano-tectonic system in northeastern Israel during the Middle Miocene.

**METHODOLOGY**

A fresh sample of the dike was collected and crushed, and a representative aliquot was dissolved in lithium metaborate (1.25 g LiBO₂) for chemical analysis. Major element analysis was determined by ICP-AES (Perkin Elmer OPTIMA 3300), and Sc was used as internal standard. For K–Ar geochronology the crushed sample was sieved to an 80–100 mesh size fraction, followed by separation of secondary minerals using a Frantz magnetic separator. Two aliquots (0.25 g each) were dissolved in LiBO₂, and K concentrations were determined using ICP-AES (%K = 0.91 ± 0.01, 1σ). Duplicates of argon analysis were performed using the standard isotope dilution procedures (K–Ar) of the geochronological laboratory at the Geological Survey of Israel (Steinitz et al., 1983; Kotlarsky et al., 1992). A hot blank of the extraction line was determined at

![Fig. 2. Road cut near Mas’ada in the southeastern flank of Mt. Hermon, showing a basaltic intrusion (west of the solid line) within the Mas’ada Formation (east of the solid line). Geologist’s hammer (indicated by an arrow) provides scale. Inset: the same road cut covered by a stone wall.](image-url)
the beginning of each measurement day and air measurements plus a hot blank were preformed at the end of that day.

RESULTS

The age obtained for the Mas’ada dike is 13.4 ± 0.2 Ma (Table 1). Petrography of the dike and the intrusion near Nahal Sa’ar indicates that they are composed of olivine basalt. The major element composition of this sample (wt %) is as follow: 44.2% SiO₂, 14.6% Al₂O₃, 10.9% Fe₂O₃, 2.5% TiO₂, 11.0% CaO, 6.2% MgO, 0.14% MnO, 4.7% Na₂O, 1.2% K₂O, 0.7% P₂O₅, and 0.3% SO₃, and loss on ignition (LOI) is 2.8%. Data were corrected for LOI and normalized to 100% and the calculated total alkalis and #Mg are 6.1 and 0.56, respectively. On a TAS diagram (% total alkalis to % silica) the Mas’ada dike is plotted on the basanite field.

DISCUSSION

The Mas’ada dike provides the first evidence that Middle-Miocene volcanic activity took place in the northern Golan Heights. It is likely that this dike was not a feeder dike for Lower Basalt flows that might have been covered later, because its periphery was arrested within the Mas’ada Formation. Hence, the dike mainly represents a sporadic occurrence of intrusive activity during that time and in that region.

Correlative volcanics of Middle-Miocene age are not known in the area west of the DST adjacent to the northern Golan Heights. There is uncertainty with regard to the area that originally was adjacent to the northern Golan Heights during dike emplacements because the amount of left-lateral offset achieved by the end of the Middle Miocene is unknown. According to Eyal et al. (1981) and Garfunkel (1981), by the end of the Middle Miocene the offset along the DST may have reached 30–50 km. In that case, a reconstruction that approximates the setting during emplacement of the Mas’ada dike indicates that the northern Golan Heights was adjacent to the area between Poriyya and Kokhav HaYarden. Reconstruction of the entire offset along the DST indicates that the northern Golan Heights was originally adjacent to the area located ~15 km south of Mt. Gilbo’a (without correcting for the deformation in the Hermon). In that area, there are several occurrences of Middle-Miocene volcanics that might be correlative to the Mas’ada dike.

The geochemical composition of Middle-Miocene volcanics was studied by Weinstein (2000), who indicated that basalts of different ages and localities range in composition from alkali-basalts to basanites, with a few hawaiites and nephelinites. He showed that basalt geochemistry varies spatially, reflecting lithospheric heterogeneity (i.e., veins are not evenly distributed in the lithosphere underneath northeastern Israel). Basanites were generated by the melting of a vein-rich lithosphere, while alkali-basalts were generated by the melting of a vein-poor lithosphere. Consequently, the basanite Mas’ada dike and the Middle-Miocene alkali-basalt volcanics from the southern Golan Heights are each fed from a different lithosphere (i.e., vein-rich and vein-poor, respectively). However, the transition area between these two distinct volcanic fields is obscured by the young basalt cover in the central and northern Golan Heights. In order to further assess the possible association between Middle-Miocene volcanics from both sides of the DST, we compared the age and geochemical composition of the Mas’ada dike to the known age and composition of volcanics from Poriyya, Giv’at HaMoreh, Mt. Gilbo’a, Yizre’el Valley, Nahal Tavor, and Kokhav HaYarden. Ages that are similar within 0.5 Ma of the dike age (13.5 ± 0.5 Ma) are known from these sites as well as from the Gideon #5 and Bira #3 boreholes (Shaliv, 1991; Weinstein, 2000). Based on this comparison, we can exclude the following areas from association with the northern Golan Heights: (1) Porriya and Nahal Tavor, due to their sub- to alkali-basalt composition, and

<table>
<thead>
<tr>
<th>Sample</th>
<th>Age (Ma)</th>
<th>(^{40}\text{Ar}_{\text{rad}}) (cc STP/g)</th>
<th>K (%)</th>
<th>(^{40}\text{Ar}_{\text{rad}}) (%)</th>
<th>(^{36}\text{Ar}_{\text{rad}}) (cc STP/g)</th>
<th>MEASID**</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW7a</td>
<td>13.3 ± 0.4</td>
<td>4.71e-07</td>
<td>0.91</td>
<td>46.42</td>
<td>1.84e-09</td>
<td>14015</td>
</tr>
<tr>
<td>SW7b</td>
<td>13.6 ± 0.3</td>
<td>4.81e-07</td>
<td>0.91</td>
<td>61.68</td>
<td>1.01e-09</td>
<td>14397</td>
</tr>
<tr>
<td>SW7average*</td>
<td>13.4 ± 0.2</td>
<td>4.76e-07</td>
<td>0.91</td>
<td>54.10</td>
<td>1.43e-09</td>
<td></td>
</tr>
</tbody>
</table>

*The average age is calculated based on the average values of \(^{40}\text{Ar}_{\text{rad}}\) (cc STP/g). rad = radiogenic.
**Number measured in the GSI Laboratory.
(2) Mt. Gilbo’a, due to its hawaiitic composition. As for Giv’at HaMoreh, Shaliv (1991) reported on two samples from this area dated \(13.5 \pm 0.4\) Ma, with unknown composition, whereas Weinstein (2000) reported on two basanite samples of unknown age. These incomplete data prevent further analysis of Giv’at HaMoreh. The remaining known areas, which are both of basanite composition and dated \(\sim 13.5\) Ma, are from the Yizre’el Valley and the lower part of the Kokhav HaYarden section.

Dikes are generally reliable indicators of the stress field existing during their emplacement because they orient themselves perpendicular to the least compression (Johnson, 1970). Likewise, the WNW-trending Mas’ada dike may indicate the orientation of the \(\sim 13.5\) Ma paleostress field, if the internal deformation of Mt. Hermon can be reconstructed. Based on paleomagnetic and structural data, Ron (1987) and Ron et al. (1990) suggest that the internal deformation of Mt. Hermon was accommodated by an approx. \(70^\circ\) counterclockwise block rotation around a vertical axis in most parts of the mountain. If most of this rotation took place after the Middle Miocene, as suggested by Ron (1987), then the original trend of the Mas’ada dike was N–S, indicating that the least horizontal compression at Mt. Hermon was oriented E–W during the Middle Miocene. This direction is compatible with the E–W least horizontal compression during the Neogene to Recent, inferred from paleostress analysis of the Newe Ativ graben (Baer et al., 1997). However, the possibility that part or most of the rotation in Mt. Hermon was achieved before \(\sim 13.5\) Ma cannot be excluded. In such a case, the WNW-trend of the dike would be close to the original, and comparable to orientations of several WNW to NW-trending dike segments of Middle to Late Miocene age in northeastern Jordan (Ron, R., Weinberger, S., Ilani, and Y. Harlavan, unpublished data) and SE Galilee (Shaliv et al., 1991).

Inferring the span and duration of the mid-Cenozoic magmatic activity in the Arabian and African plates is commonly complicated by the fact that younger volcanics usually cover older ones. The present study sheds some new light on the Middle-Miocene volcanic activity previously obscured in the southeastern flank of Mt. Hermon.

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REFERENCES


